CEPC-SPPC总体介绍及概念设计

秦 庆

中国科学院高能物理研究所

2016年4月28日

Acknowledgement

- 王贻芳，娄辛丑，唐靖宇，高杰，耿会平，徐庆金，等
- 高温与高场超导材料极其应用技术研讨会

主要内容

主 要 内 容

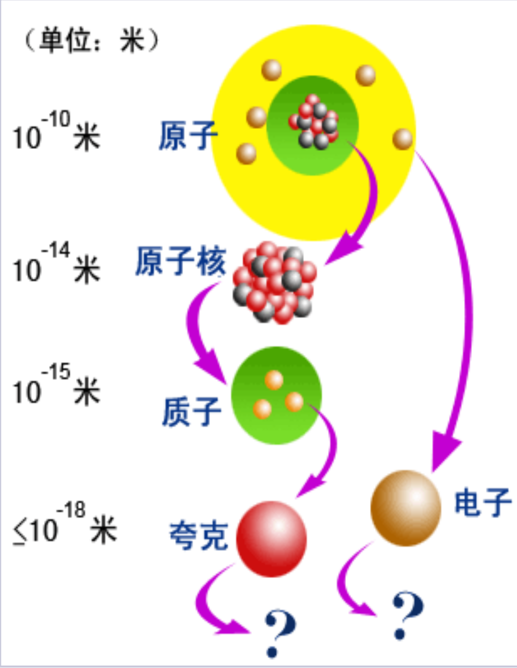
1. 引言 粒子物理研究及其未来发展

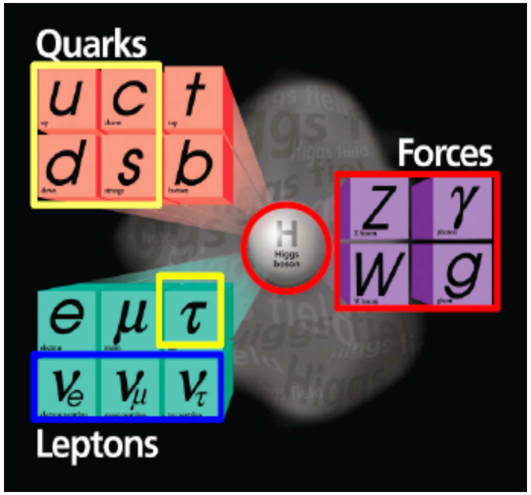
- 物质世界的基本组分及其相互作用是自然界最基本的科学问题之一

  物质微观结构的研究引领了科学发展几百年

- 粒子物理研究在近代取得了辉煌成就
  - 标准模型取得了巨大成功（9次诺贝尔奖）
  - 发现了构造物质世界的所有“基本粒子”，其性质与标准模型预言符合（8次诺贝尔奖）

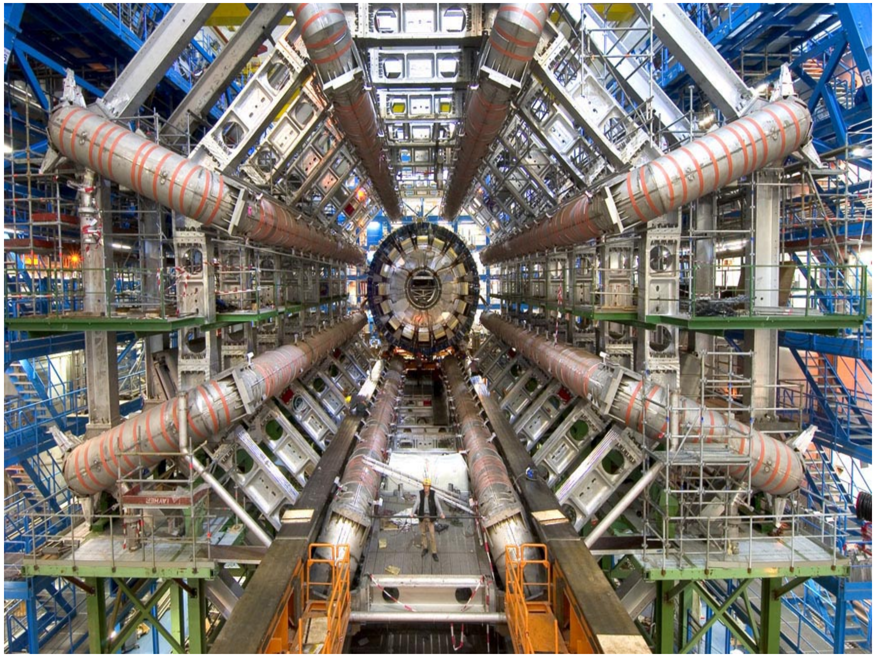
    最后一个是2012年发现的希格斯粒子
  - 相关的加速器与探测器技术进步巨大，并得到广泛应用(3次诺贝尔奖）
- 但标准模型并不能解释所有实验现象，本身也不完备。
- 2012年7月，Higgs粒子在LHC上被发现
- 标准模型“完备”以后，粒子物理向何处去

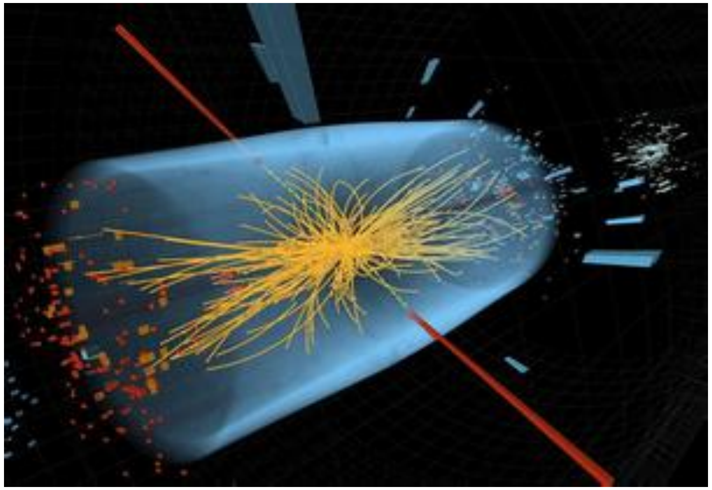




1. 引言

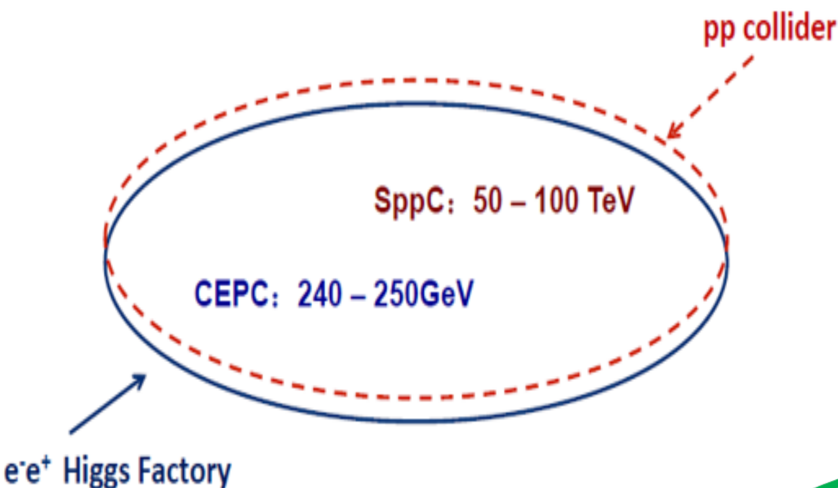
Higgs粒子的发现

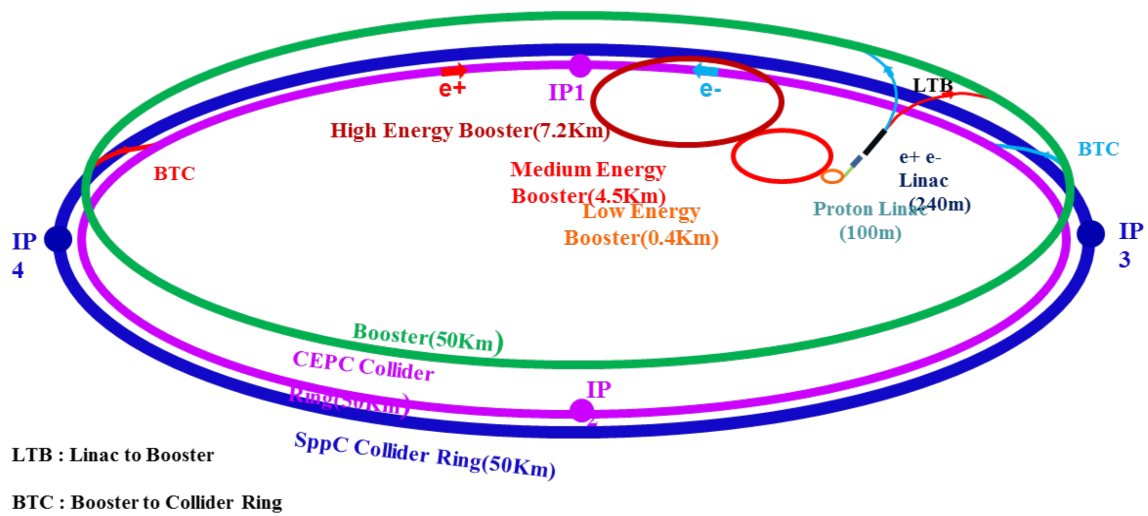




重大机遇

- 质量~126GeV/c^2为环形对撞机提供了重大机遇
- 2012年9月提出建造CEPC-SppC的设想





国际影响

- 2012年11月在“Workshop on Accelerators for Higgs Factory: Linear vs Circular”上报告中国的设想，引起很大反响
- 2014年国际高能物理大会，专门对此进行讨论

2014年国际高能物理大会关于未来的讨论

- 国外许多科学杂志和报纸均报道和评论了此事。如时任ICFA主席，美国费米国家实验室主任Nigel Lockyer 在《自然》（V504,18 Dec.2013）发表文章，评述此事

ILLUSTRATION BY SCOTT GARRETT

Together to the next frontier

As emerging players jostle old ambitions, **Nigel Lockyer** calls for the next generation of particle-physics projects to be coordinated on a global scale.

This year was a watershed for particle physics. The decades-long quest to discover the Higgs boson is essentially complete. Still abuzz after a Nobel prize for the Higgs prediction, the particle-physics community is feeling satisfied. It is time to pause, reflect and consider what comes next.

The Higgs boson is the last puzzle piece in the standard model of particle physics, but the model does not explain some fundamental aspects of our Universe. From the neutrino's very small mass to dark matter and dark energy, we know there is more going on. But where might the next clue lurk?

We really don't know. Each physicist has his or her own opinion, and countries and regions are preparing to explore different strategies to identify the territories ripest for exploration. What we do know is that the next generation of particle accelerators will be expensive. And requests for government funding will run up against fiscal constraint around the globe.

➲ NATURE.COM
See *Nature*'s special issue on the Large Hadron Collider:
nature.com/lhc

As the incoming director of the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois, I have spent the past six months in discussions about the future of US particle physics. But particle physics is an international pursuit, with projects in and participants from many different countries. The United States is well positioned to take the lead in some areas, such as neutrino physics, but the global landscape is uncertain. Resources need to be pooled, and new players are emerging. China's and India's talent, infrastructure and ambitions must now be factored into the global equation.

We are at a critical moment for the field. Each country and major project ▸

origin of their tiny ma... the early Universe. Fer... is heading a US proposal to build a long ne...ino-beam experiment, running 1,300 kilometre... from Fermilab to the Homestake mine in Sou... Dakota. An ambitious 35-kilotonne liquid argon detector located nearly 1,500 metres below the surface emerged as the preferred project when the US community met in Minnesota for a ten-day planning symposium in July. It would help us to understand neutrino masses and whether these particles contribute to the matter–antimatter asymmetry of the Universe.

With the total construction budget nearing $1 billion, the experiment will require international partners — a new approach for US domestic science. The US Department of Energy's Office of Science has indicated that it would support such a major proposal if there was involvement from

up in the 2030s.

And the United States still ha... ambitions to host a high-energy fr...tier machine, ...fter turning off the Fermilab's Tevatron accelerator in 2011 and failing to realize the Superconducting Super Collider in the 1990s. Perhaps the high-energy baton could be passed back to the United States. Fermilab is still a world leader in high-field magnets for proton accelerators, which would be necessary for any 100-TeV proton–proton collider.

"If China does jump ahead, it will change the landscape of science."

To add to the suspense, there is the changing role of China. Historically a small player in particle physics, it last year stepped onto the world stage with

Fermilab and the High Energy Accelerator Research Organization (KEK) in Tsukuba, Japan: these are the only places where large particle-physics projects are currently feasible. Demands from emerging economies such as China to host other projects will challenge the long-term plans of the existing leaders. Scientists in the United States and Europe will have to find out how best to use international competition as a spur for advancing projects on their own soil while still being good international partners. This may become tricky.

Higgs bosons are not export-controlled, nor are pictures of deep space from advanced telescopes. But the technologies developed, often through international collaborations, may have dual use — for defence applications or for economic gains, for example, as well as for basic science. Countries will have to decide how to oversee and exploit these

another has neutrinos travelling across Japan. But the world can afford only one.

Japan is perhaps the stiffest competitor, with leading programmes in neutrino physics, a bottom-quark ('b-quark') factory and kaon and muon experiments. The country

symmetry differences between neutrinos and antineutrinos might be observable in a long-baseline experiment, telling us about matter and antimatter imbalances in the early Universe. Emboldened, might the Chinese leapfrog the world by hosting

understand how the Universe works. ■

Nigel Lockyer *is director of the Fermi National Accelerator Laboratory in Batavia, Illinois.*
e-mail: lockyer@fnal.gov

368 | NATURE | VOL 504 | 19/26 DECEMBER 2013

国内外广泛共识

- **2013年6月12-14日**香山会议：“环形正负电子对撞机**Higgs**工厂**(CEPC)+** 超级质子对撞机**(SppC)**是我国高能物理发展的重要选项和机遇”
- 随后的第三届和第四届“中国高能加速器物理战略发展研讨会”：“环形正负电子对撞机**Higgs**工厂**+** 超级质子对撞机是我国未来高能物理发展的首要选项”
- **2014年2月**在汉堡召开的国际未来加速器委员会**(ICFA)**做出如下结论：

ICFA supports studies of energy frontier circular colliders and encourages global coordination

- **2014年7月**的**ICFA**会议再次强调：

… ICFA continues to encourage international studies of circular colliders, with an ultimate goal of proton-proton collisions at energies much higher than those of the LHC.

1. 引言

国际竞争

CERN提出FCC计划，并因为中国提出CEPC-SppC而日益重视FCC，推动未来高能对撞机的发展

Goal: CDR (including cost estimate) by end 2018
(in time for next European Strategy)

International conceptual design study:

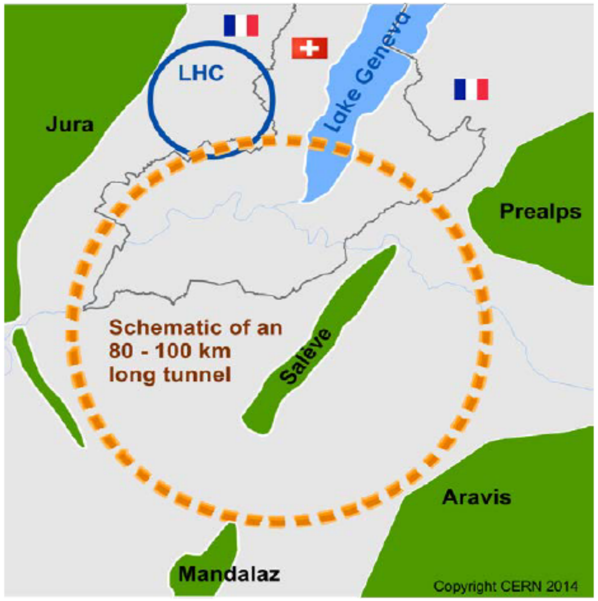
- ❑ pp collider (FCC-hh): ultimate goal
  → defines infrastructure requirements;

  ~ 100 km ring; 16 T magnets

  $\sqrt{s}$ ~ 100 TeV, L~2x10^{35}; 4 IP, ~20 ab^{-1}/expt
- ❑ e^+e^- collider (FCC-ee): possible first step

  $\sqrt{s}$ = 90-350 GeV, L~70-1.3 x 10^{34}; 2 IP
- ❑ pe collider (FCC-he): option

  $\sqrt{s}$ ~ 3.5 TeV, L~10^{34}



Also part of the study: HE-LHC: ~16 T dipoles in LHC tunnel → $\sqrt{s}$ ~ 30 TeV

FCC(ee, hh) CDR Goals

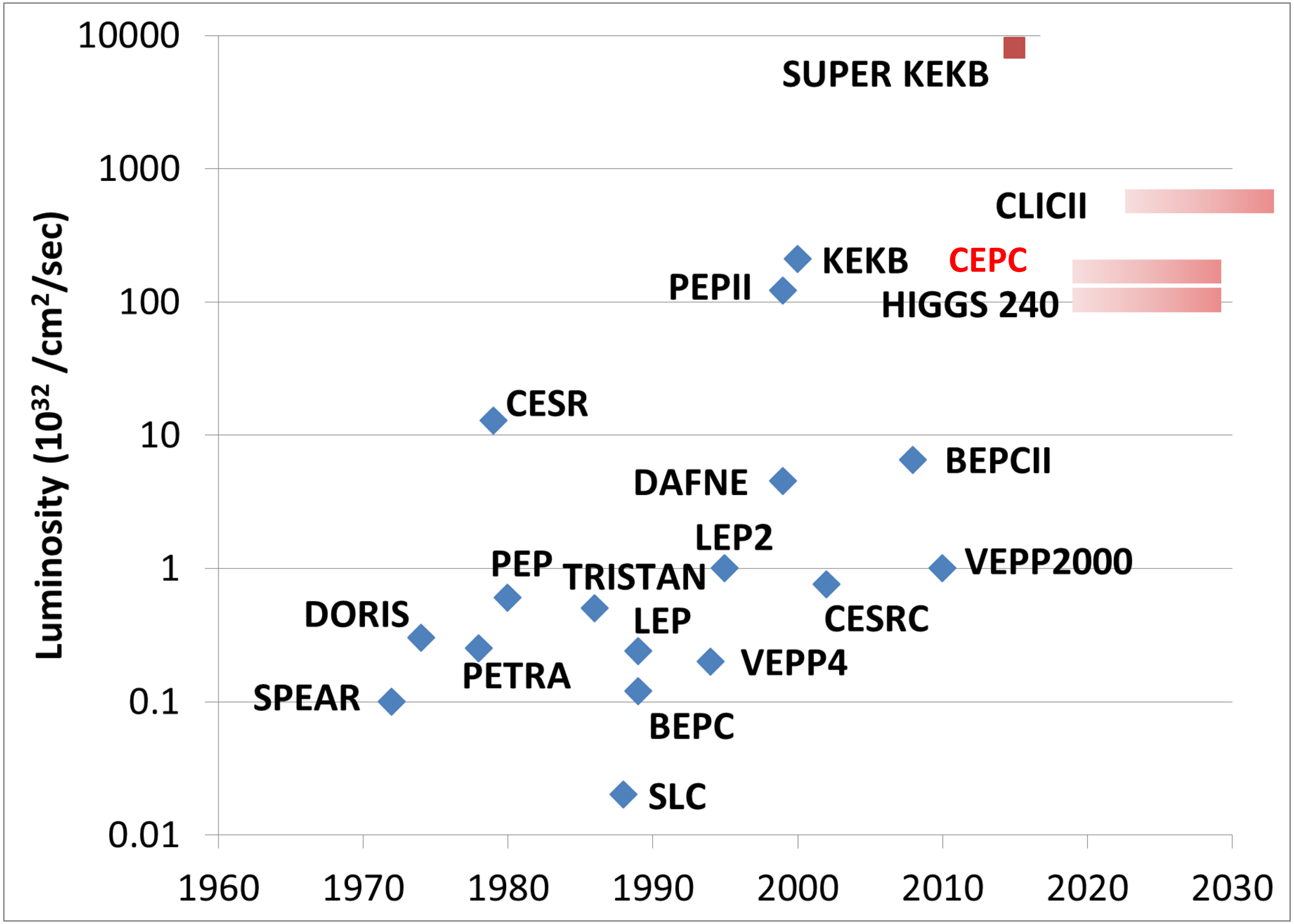
- ❑ Strong physics case if new physics from LHC/HL-LHC
- ❑ Powerful demonstration of the FCC-hh magnet technology

Fabiola Gianotti

科学目标

- 正负电子对撞CEPC (90 - 250 GeV)
  - 希格斯工厂(250 GeV 处产生 ~ 10^6 个希格斯粒子）
    - 精确测量与研究希格斯粒子(质量、自旋、宇称、耦合等）
  - Z & W 工厂(90 GeV 处产生每年 10^{10}个Z 粒子)
    - 精确检验标准模型
    - 寻找偏离标准模型的迹象，稀有衰变等
  - 味工厂(Z衰变产生大量的B介子，粲介子与tau 轻子）
- 质子质子对撞(~100 TeV)
  - 直接寻找超出标准模型的新物理、新现象和新粒子
  - 标准模型的精确测量
  - 寻找暗物质粒子

1. 引言 物理需求 — 亮度



Luminosity (10^{32} /cm^2/sec)
10000
1000
100
10
1
0.1
0.01
1960
1970
1980
1990
2000
2010
2020
2030
SUPER KEKB
CLICII
KEKB
CEPC
PEPII
HIGGS 240
CESR
BEPCII
DAFNE
LEP2
PEP
TRISTAN
VEPP2000
DORIS
LEP
CESRC
VEPP4
PETRA
SPEAR
BEPC
SLC

时间计划

- CEPC
  - Pre-CDR studyR&D and preparation work
    - Pre-study: 2013-15 → Pre-CDR by the end of 2014
    - R&D: 2016-2020
    - Engineering Design: 2015-2020
  - Construction: 2021 – 2027
  - Data taking: 2030 – 2036
- SppC
  - Pre-study, R&D and preparation work
    - Pre-study: 2013-2020
    - R&D: 2020-2030
    - Engineering Design: 2030-2035
  - Construction: 2036-2042
  - Data taking: 2042 -

建设选址

延庆县
G101
密云县
G45
兴隆县
G112
青龙满族
自治县
怀柔区
昌平区
遵化市
顺义区
平谷区
迁西县
G110
蓟县
迁安市
三河市
秦皇岛市
门头沟区
北京市
G102
通州区
玉田县
G1
卢龙县
抚宁县
G205
G025
丰润区
北戴河区
108
G4
香河县
G1
大兴区
宝坻区
古冶区
滦县
G205
昌黎县
唐山市
G2
廊坊市
G103
丰南区
涿州市
滦南县
乐亭县
武清区
G2501
宁河县
碑店市

S269
S363
S251
S266
S023
CepC, SppC
S048
山海关区
G1
秦皇岛市
高能所
G102
50 km
抚宁县
S267
G205
Google earth

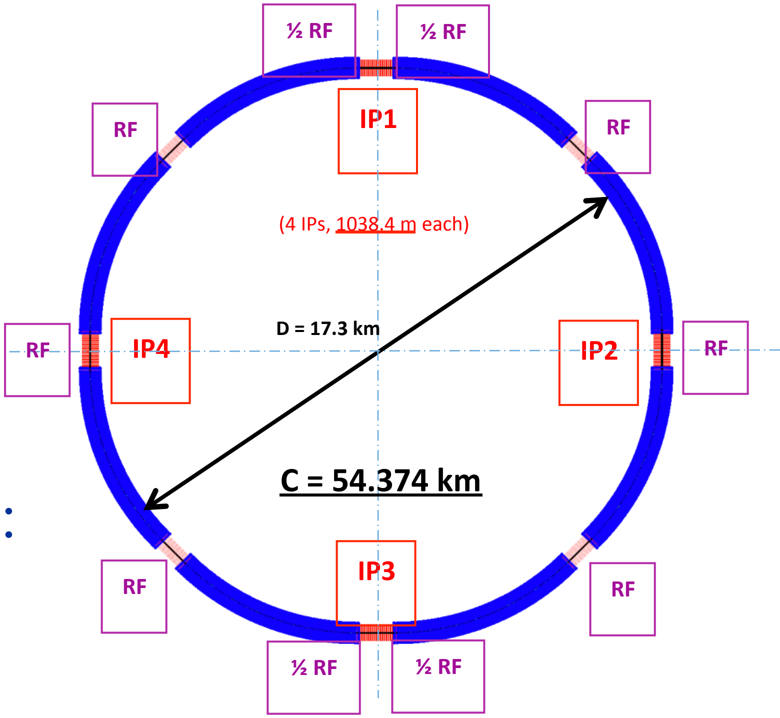
组织队伍，启动研究

CEPC+SppC Kick off Meeting, Sept. 13-14,2013, Beijing

About 110 participants and 20 institutions registered.

1. 引言 CEPC-SppC参考方案设计

- CEPC初步概念设计基本完成，并公开发表
- 推进CEPC关键技术预研，所创新经费启动支持
  - 部分加速器、探测器关键技术研发启动
- 完成基准（秦皇岛）选址初步勘探
- 谋划中国高能物理的未来发展
  - 香山科学会议第464次学术讨论会综述：《下一代高能正负电子对撞机：现状与对策》
  - 基于加速器的高能物理发展战略研讨会



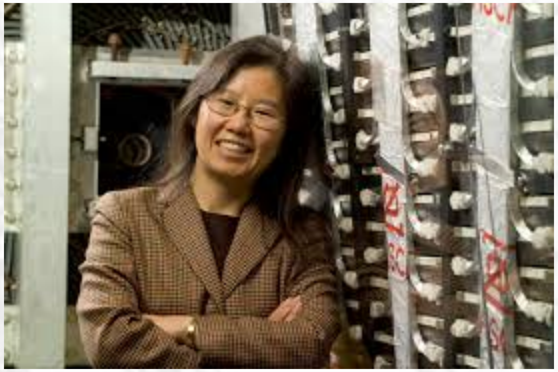
1. 引言

CEPC国际顾问委员会（IAC）

No.	Name	Sep. 16-17	Email	Field	Institution	Country
1	David Gross	Yes	gross@kitp.ucsb.edu	Theory	UC Santa Barbara	USA
2	Luciano Maiani	yes	luciano.maiani@roma1.infn.it	Theory	U. Rome	Italy
3	Michelangelo Mangano	No	michelangelo.mangano@cern.ch	Theory	CERN	CERN
4	Joe Lykken	yes	lykken@fnal.gov	Theory	Fermilab	USA
5	Henry Tye	yes	iastye@ust.hk	Theory	IAS, HKUST	Hong Kong
6	Hitoshi Murayama	No	hitoshi.murayama@ipmu.jp	Theory	IPMU/UC Berkeley	Japan
7	Rohini Godbole	No	rohini@cts.iisc.ernet.in	Theory	CHEP, Bangalore	India
8	Katsunobu Oide	Yes	oide1@icloud.com	Accel.	KEK	Japan
9	Steinar Stapnes	Yes	Steinar.Stapnes@cern.ch	Accel.	CERN	Norway
10	John Seeman	Yes	seeman@slac.stanford.edu	Accel.	SLAC	USA
11	Eugene Levichev	Yes	E.B.Levichev@inp.nsk.su	Accel.	BINP	Russia
12	Robert Palmer	Yes	palmer@bnl.gov	Accel.	BNL	USA
13	Hesheng Chen	Yes	chenhs@ihep.ac.cn	Exp.	IHEP	China
14	Eckhard Elsen	No	Eckhard.Elsen@desy.de	Exp.	DESY	Germany
15	Peter Jenni	No	Peter.Jenni@cern.ch	Exp.	CERN	CERN
16	Harry Weerts	Yes	weerts@anl.gov	Exp.	ANL	USA
17	Young-Kee Kim	yes	ykkim@hep.uchicago.edu	Exp.	U. Chicago	USA
18	Ian Shipsey	No	shipsey@physics.ox.ac.uk	Exp.	Oxford	UK
19	Michael Davier	Yes	davier@lal.in2p3.fr	Exp.	LAL	France
20	Geoffrey Tayler	Yes	gntaylor@unimelb.edu.au	Exp.	U. Melbourne	Australia
21	George Hou	Yes	wshou@phys.ntu.edu.tw	Exp.	Taiwan U.	Taiwan
22	Lucie Linssen	Yes	Lucie.Linssen@cern.ch	Exp.	CERN	UK
23	Barry Barish	Yes	barish@ligo.caltech.edu	Exp.	Caltech	USA
25	Brian Foster	Yes	Brian.Foster@desy.de	Exp.	DESY/U. Hamburg	Germany

formed in summer 2015, first meeting Sept. 16-17

IAC chaired by Prof. Young-Kee Kim



- ✓ Great committee members
- ✓ Countries and regions well represented
- ✓ Full range of expertizes

CEPC Organization IAC

The CEPC International Advisory Committee

September 8, 2015

Charge

The Circular Electron Positron Collider（CEPC） Study Group， currently hosted by the Institute of High Energy Physics, Chinese Academy of Sciences, has completed a preliminary Conceptual Design Report and has applied for R&D funding to the Chinese government. The CEPC Study Group is now trying to expand its overall scope and composition, and will move towards the R&D phase.

The underlying assumption is that the CEPC R&D will be funded for the next five years, and the group will embark on the CDR and TDR process during the period in a global effort. Through this period the most critical accelerator and detector designs and key technologies will be worked out and demonstrated, paving the way for the eventual construction of the CEPC facilities after the completion of the R&D phase.

CEPC will be an international project. International community shall be involved even at this initial phase to develop the strategy and the roadmap, and to determine the choice of the science to be focused on, the technologies to adopt and the approach to handle geopolitical issues. The CEPC International Advisory Committee shall advise on all related matters for the CEPC project, specifically on the following aspects:

1. What should be the strategy for CEPC to go global in the design and the R&D effort?
2. How should an internationalized CEPC be organized and governed?
3. How should the CEPC collaborate with other efforts such as the ILC and the FCC?
4. What are the right phased approaches for the realization of the CEPC?
5. How can the cost be shared among the nations? How do we handle the diplomacy and politics issues?
6. How through global efforts can the CEPC accelerator and detector achieve a great design that can be realized at a reasonable cost and within a reasonable construction period?
7. How can we build a world class CEPC laboratory in China for the world's particle physics?

The committee is invited to give suggestions or advice on any aspect of CEPC beyond those specifically included in this charge.

主 要 内 容

一 引言

二 CEPC加速器物理与技术研究进展

三 SppC加速器概要

四 总结

2. CEPC 初步设计

2015年完成初步概念设计报告及评审

IHEP-CEPC-DR-2015-01

IHEP-EP-2015-01

IHEP-TH-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

Volume I - Physics & Detector

The CEPC-SPPC Study Group

March 2015

IHEP-CEPC-DR-2015-01

IHEP-AC-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

Volume II - Accelerator

The CEPC-SPPC Study Group

March 2015

初步概念设计 — 科学目标、加速器和探测器、初步地质调查、需求分析和隧道及辅助设施

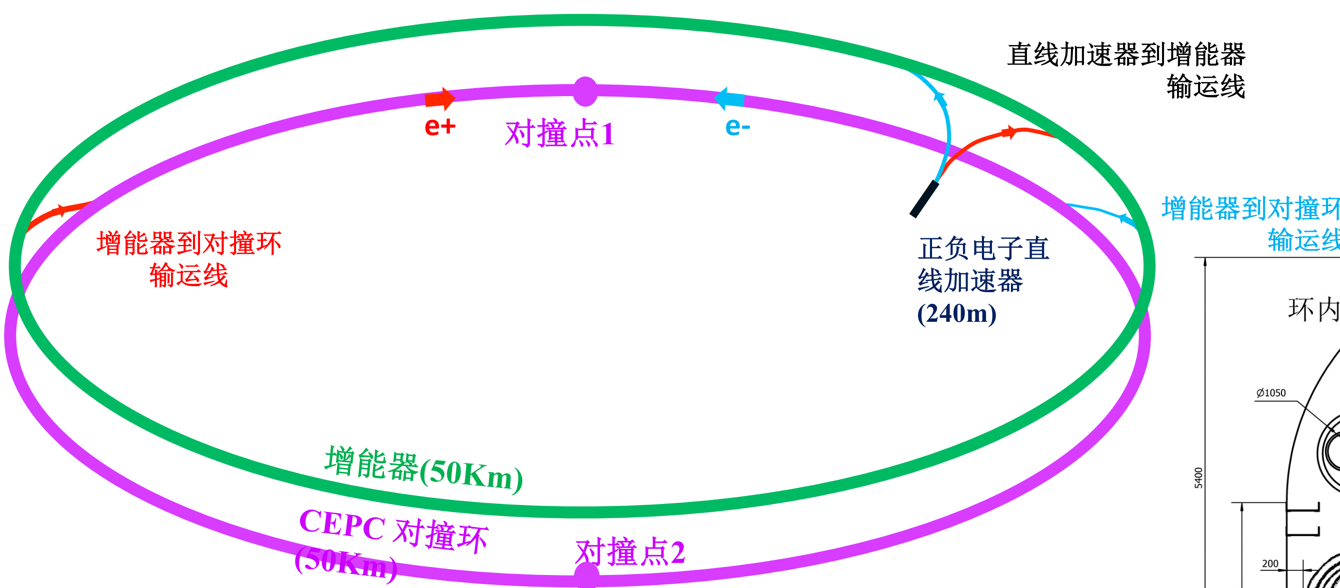
http://cepc.ihep.ac.cn/preCDR/volume.html

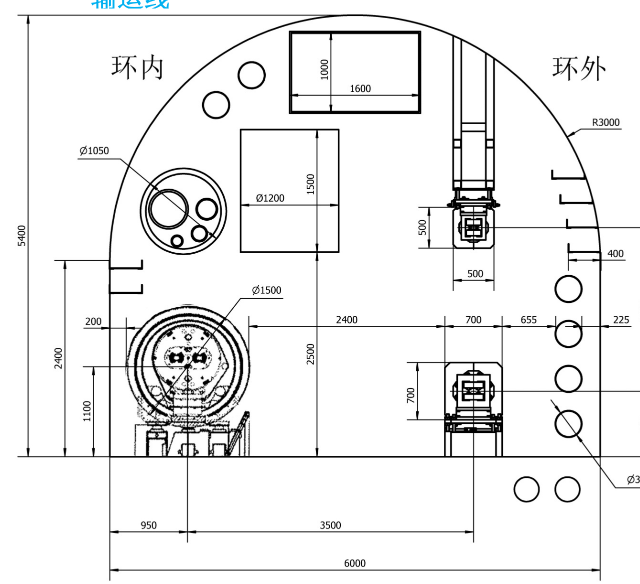
2. CEPC 初步设计

CEPC加速器设计

- 直线加速器（LINAC）
  - 产生电子并加速至6 GeV
- 增强器 （booster）
  - 加速电子至120 GeV

- 主环（main ring）
  - 积累电子至16.9 mA

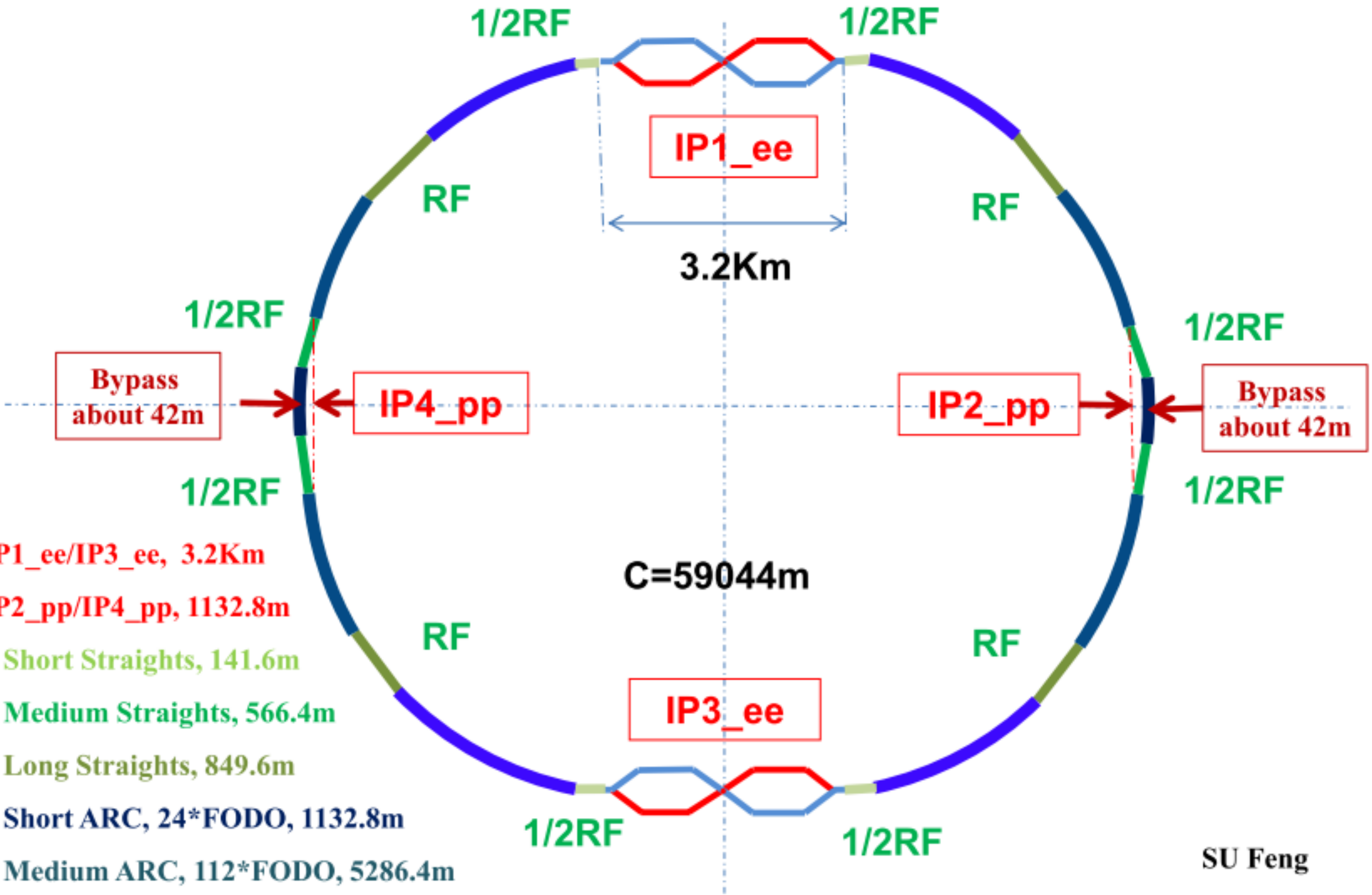




近期研究进展

- 加速器物理
  - Partial double ring
  - Parameter
  - Single ring
  - DA optimization
  - Collective instabilities
  - Booster
  - Injector

CEPC Partial Double Ring Layout



IP1_ee/IP3_ee, 3.2Km

IP2_pp/IP4_pp, 1132.8m

4 Short Straights, 141.6m

4 Medium Straights, 566.4m

4 Long Straights, 849.6m

2 Short ARC, 24*FODO, 1132.8m

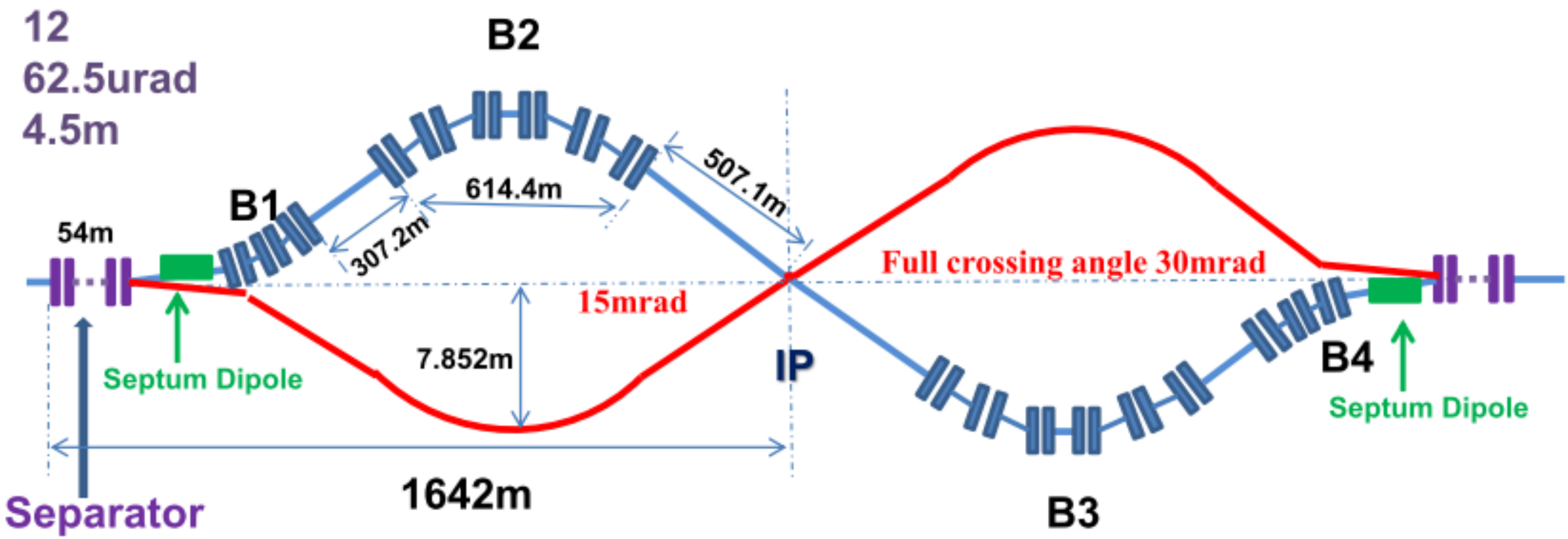
4 Medium ARC, 112*FODO, 5286.4m

4 Long ARC, 124*FODO, 5852.8m

SU Feng

2016.1.4

CEPC Partial Double Ring Layout



For CEPC 120GeV beam:

➢Max. deflection per separator is 66μrad.

Using Septum Dipole after separator to acquire 15 mrad

Version 1.0

sufeng

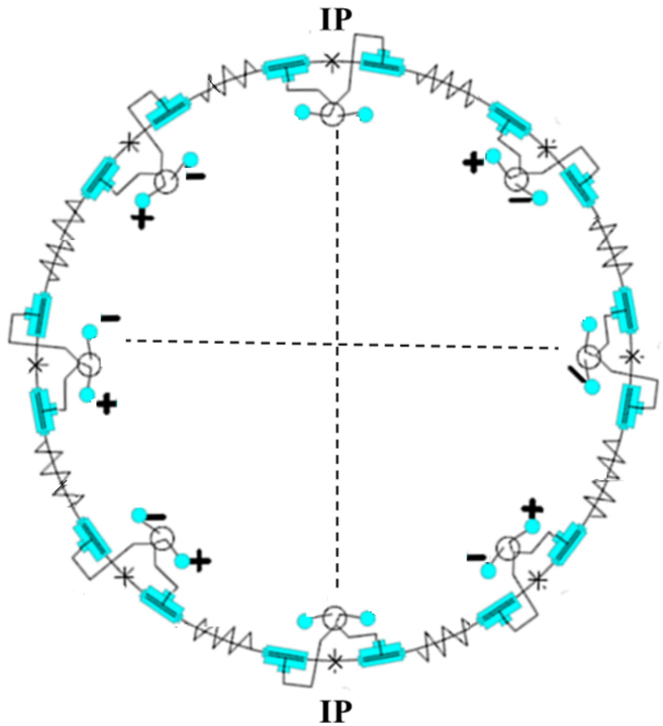
2015.12.20

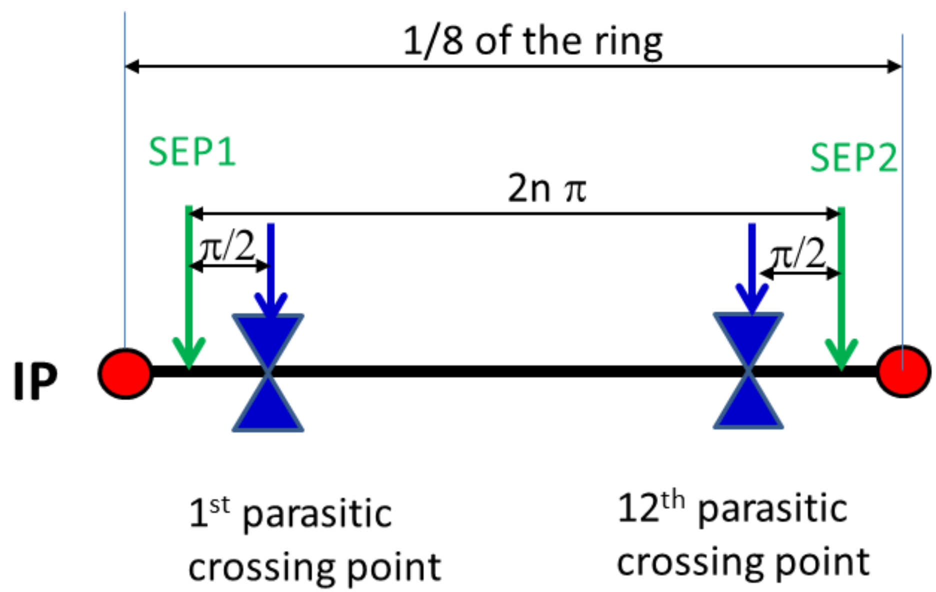
Main parameter for CEPC partial double ring

	Pre-CDR	***H-high lumi.***	***H-low power***	***W***	***Z***
Number of IPs	2	2	2	2	2
Energy (GeV)	120	120	120	80	45.5
Circumference (km)	54	54	54	54	54
SR loss/turn (GeV)	3.1	2.96	2.96	0.59	0.062
Half crossing angle (mrad)	0	15	15	15	15
Piwinski angle	0	2.5	2.6	5	7.6
N_e/bunch (10^{11})	3.79	2.85	2.67	0.74	0.46
Bunch number	50	67	44	400	1100
Beam current (mA)	16.6	16.9	10.5	26.2	45.4
SR power /beam (MW)	51.7	50	31.2	15.6	2.8
Bending radius (km)	6.1	6.2	6.2	6.1	6.1
Momentum compaction (10^{-5})	3.4	2.5	2.2	2.4	3.5
β_{IP} x/y (m)	0.8/0.0012	0.25/0.00136	0.268 /0.00124	0.1/0.001	0.1/0.001
Emittance x/y (nm)	6.12/0.018	2.45/0.0074	2.06 /0.0062	1.02/0.003	0.62/0.0028
Transverse σ_{IP} (um)	69.97/0.15	24.8/0.1	23.5/0.088	10.1/0.056	7.9/0.053
ξ_x/IP	0.118	0.03	0.032	0.008	0.006
ξ_y/IP	0.083	0.11	0.11	0.074	0.073
V_{RF} (GV)	6.87	**3.62**	**3.53**	**0.81**	**0.12**
f_{RF} (MHz)	650	650	650	650	650
Nature σ_z (mm)	2.14	**3.1**	**3.0**	**3.25**	**3.9**
Total σ_z (mm)	2.65	4.1	4.0	3.35	4.0
HOM power/cavity (kw)	3.6	2.2	1.3	0.99	0.99
Energy spread (%)	0.13	0.13	0.13	0.09	0.05
Energy acceptance (%)	2	2	2		
Energy acceptance by RF (%)	6	**2.2**	**2.1**	**1.7**	**1.1**
n_γ	0.23	0.47	0.47	0.3	0.24
Life time due to beamstrahlung_cal (minute)	47	36	32		
F (hour glass)	0.68	0.82	0.81	0.92	0.95
L_{max}/IP (10^{34}cm^{-2}s^{-1})	2.04	2.96	2.01	3.09	3.09

Single ring with pretzel orbit

- Designed for 50 bunches/beam, every 4pi phase advance has one collision point
- Horizontal separation is adopted to avoid big coupling
- No off-center orbit in RF section to avoid beam instability and HOM in the cavity
- One pair of electrostatic separators for each arc

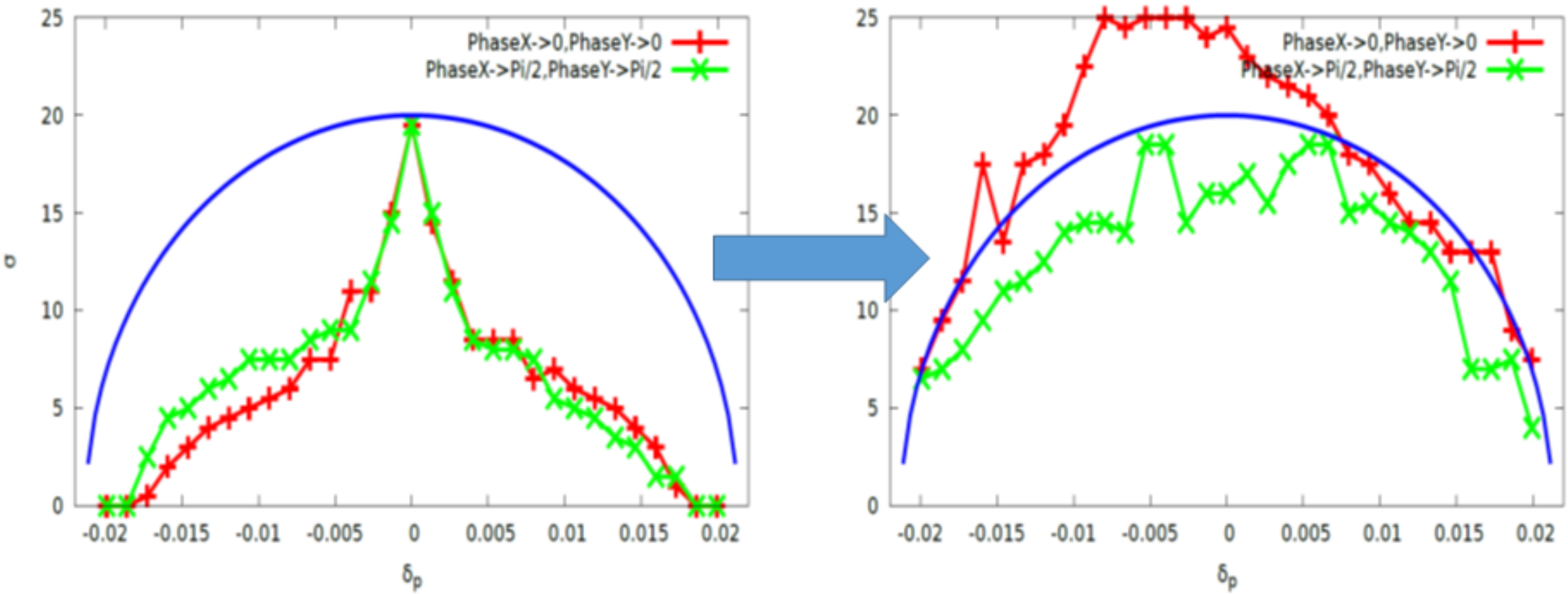




DA optimization with MODE

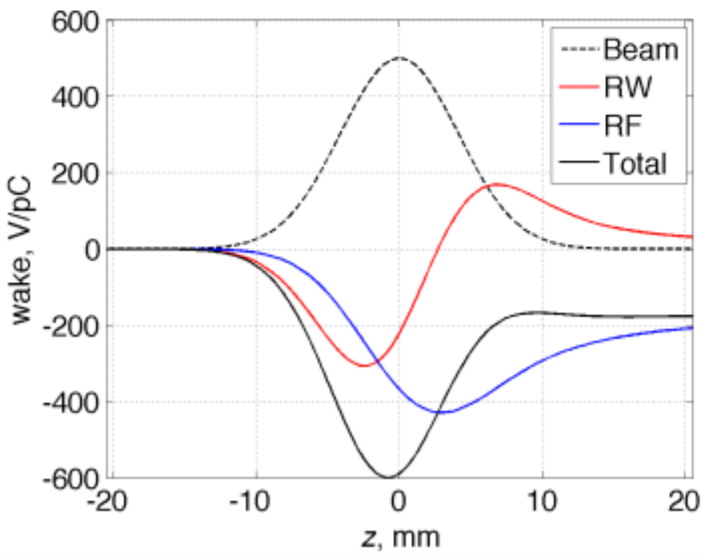
(a self developed multi-objective code)

CEPC: Dynamic Aperture Optimization with 240 sextupoles in ARC (v1-IR)



- CEPC ring wake and impedance budget

Object	Contributions			
	R [kΩ]	L [nH]	k_{loss} [V/pC]	$\|Z_{//}/n\|_{eff}$ [Ω]
Resistive wall	6.1	154.7	146.8	0.017
RF cavities (N=384)	14.9	-132.7	307.5	0.005
Total	21.0	22.0	454.3	0.022



Longitudinal wake at nominal bunch length (σ_z=4.1mm)

$$W(s) = -Rc\lambda(s) - Lc^2\lambda'(s)$$

$$\kappa_{loss} = \int_{-\infty}^{\infty} ds W(s)\lambda(s)$$

$$\left(\frac{Z_{\parallel}}{n}\right)_{eff} = \frac{\sum_{p=-\infty}^{\infty} \frac{Z_{\parallel}(\omega_p)}{\omega_p} h_m(\omega_p)}{\sum_{p=-\infty}^{\infty} h_m(\omega_p)}$$

$$\omega_p = \omega_0(p+\mu+m\nu_s)$$

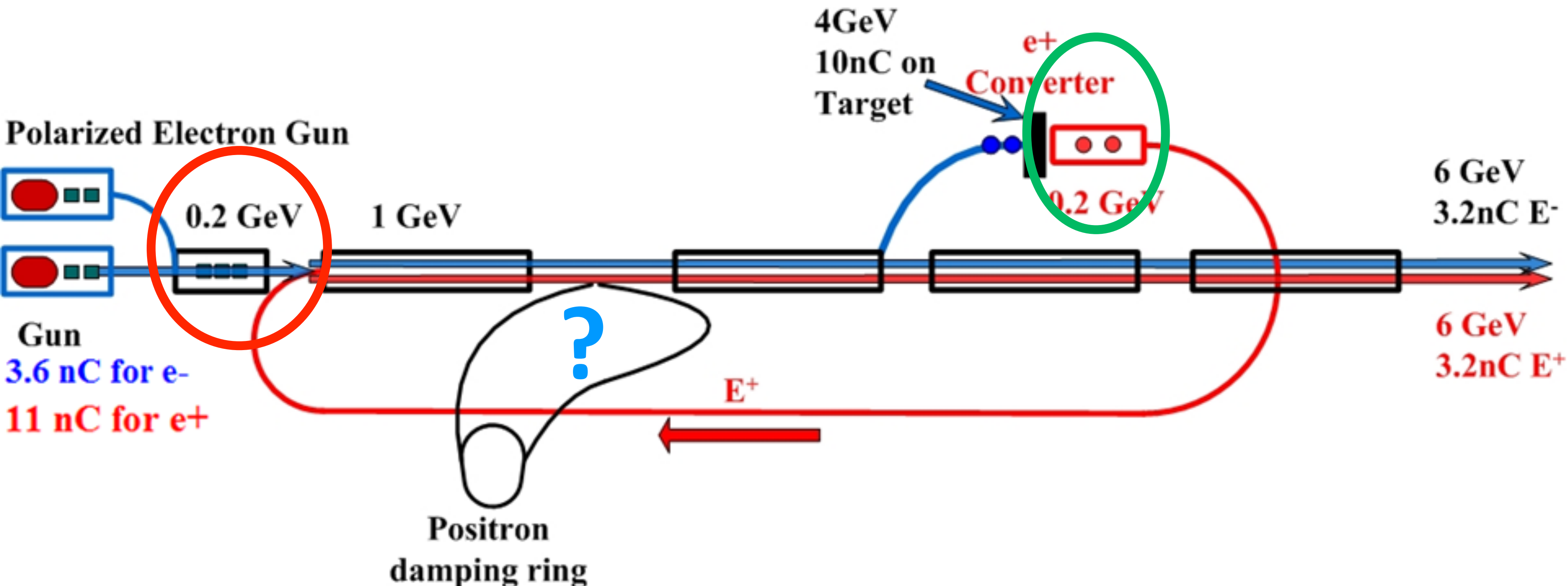
$$h_m(\omega) = (\omega\sigma_\tau)^{2m} e^{-\omega^2\sigma_\tau^2}$$

- The loss factor is dominated by the RF cavities.
- More complete impedance budget is needed.

Magnetic field measurement in BEPCII tunnel

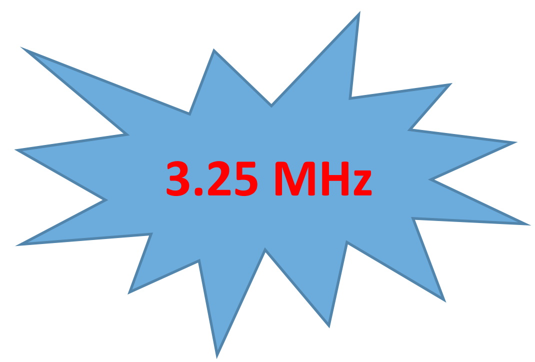
- 1.6 ~ 2 Gauss magnetic field is found at all places far from accelerator magnets in the BEPCII tunnel;
- This indicates that power cabling is one of major sources of the background field;
- Careful design of cabling system is proposed.

CEPC Injector Layout

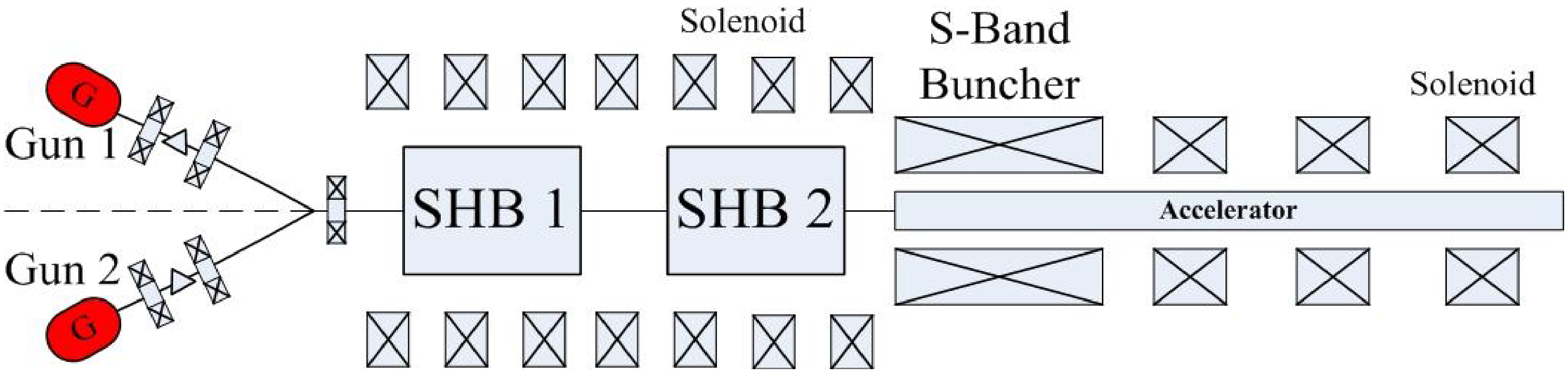


- 频率选择
  - Booster频率为1300MHz
  - 直线加速器的频率选**2856.75**MHz

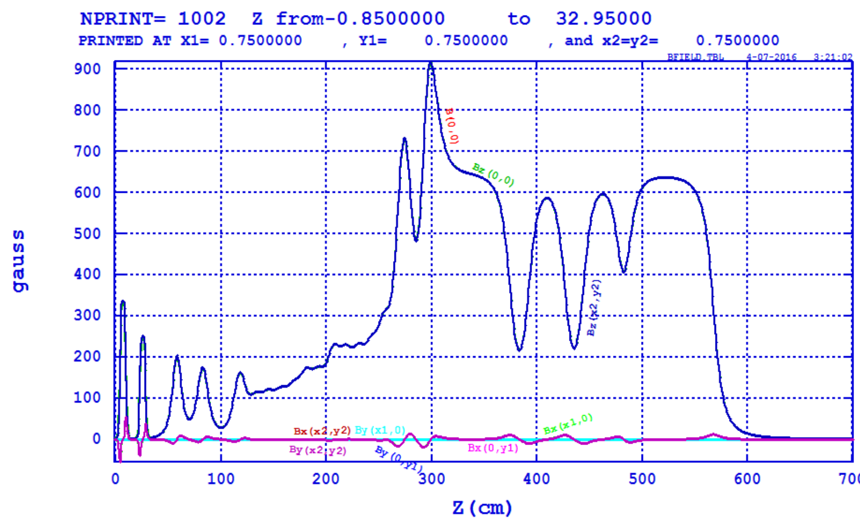
其中， 2856.75MHz=3.25MHz×879，
1300MHz=3.25MHz×400MHz



Electron linac Lattice



- **Bunching System**
  - SHB1:142.8375 MHz
  - SHB： 571.35 MHz
  - S-band Buncher (1): 2856.75 MHz
- First accelerating structure
  - S-band accelerator (3): 2856.75 MHz ~ 24 MV/m



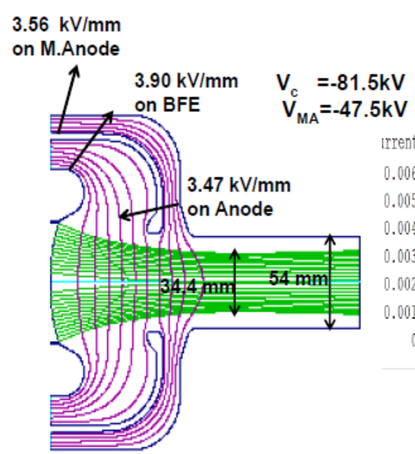
加速器关键技术

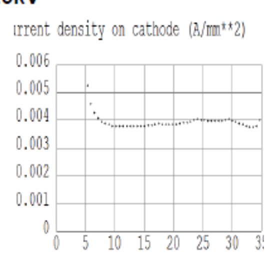
- 功率源系统
- 超导高频系统
- 低温系统
- 束流测量系统
- 机械准直系统
- 磁铁系统
- 磁铁电源系统
- 控制系统
- 等等

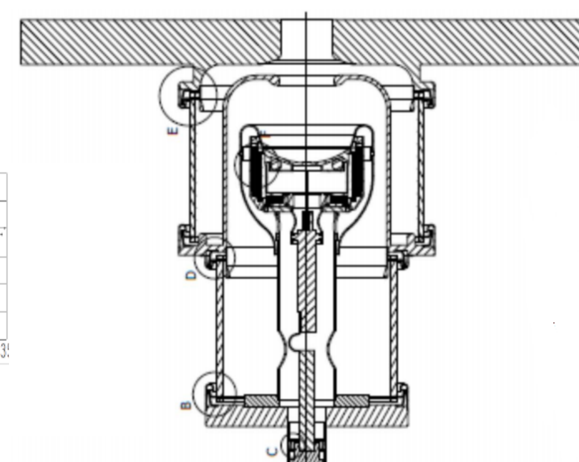
功率源系统 — 速调管研制进展

Year	2015			2016											2017		
Month	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Cathode			Cathode Order														
Ceramic				Ceramic Order													
			Gun Design			Copper Block											
			Coil/Socket														
					Collector Design												
Total Design																	
Drawing			Auto Inventor														
Start Manufacturing							manufacturing				Baking						
Test										Gun test							
Klystron Design		Classical Design								Comparison							
			2nd similation /Output cavity														
										High Efficiency Design							
Window Design					Window design/Drawing												
							manufacturing		Testing								

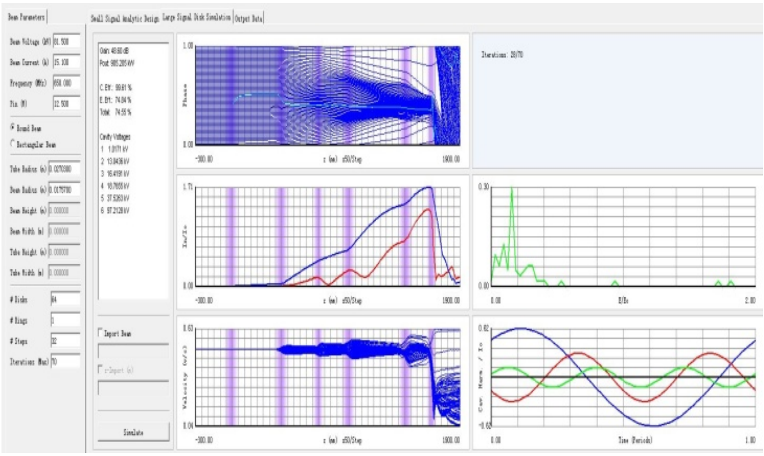
参数	数值
阴极电压	-81.5kV
调制阳极电压	-47.5kV
导流系数	0.64 $\mu A/V^{3/2}$
最大表面电场强度	3.9MV/m
阴极电流密度	0.45A/cm^2
阴极电流密度均匀度	1.24

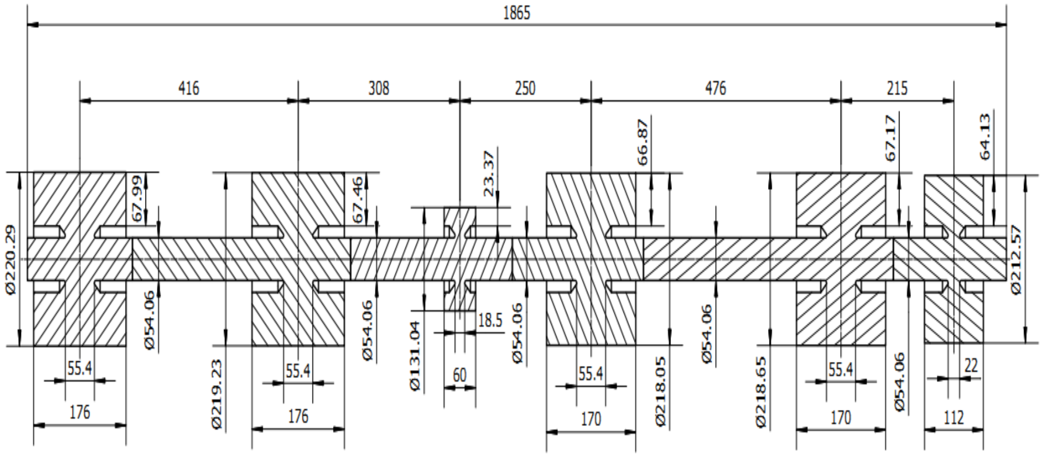






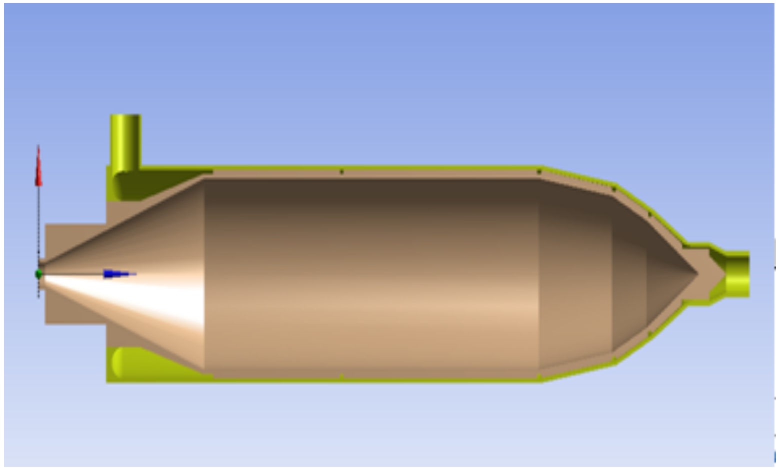
射频互作用段

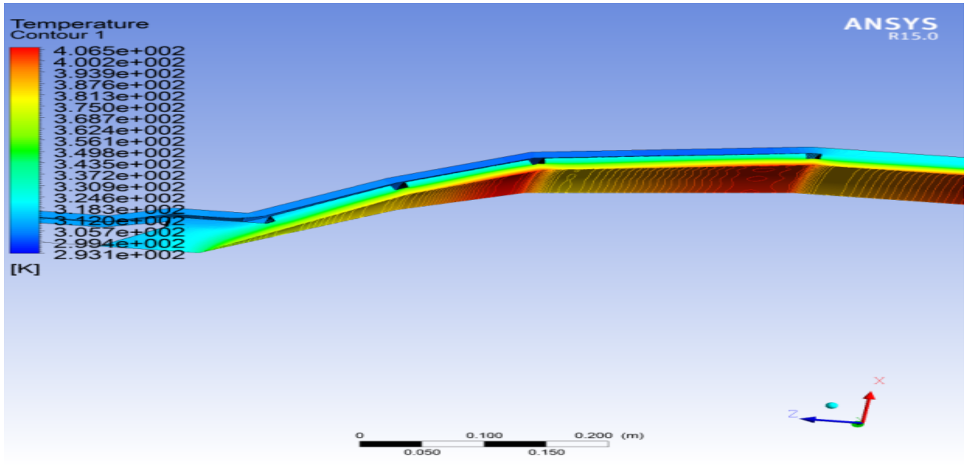




1865
416
308
250
476
215
Ø220.29
67.99
67.46
23.37
66.87
67.17
64.13
Ø212.57
Ø54.06
Ø219.23
Ø131.04
18.5
60
Ø218.05
Ø218.65
55.4
176
170
112
22

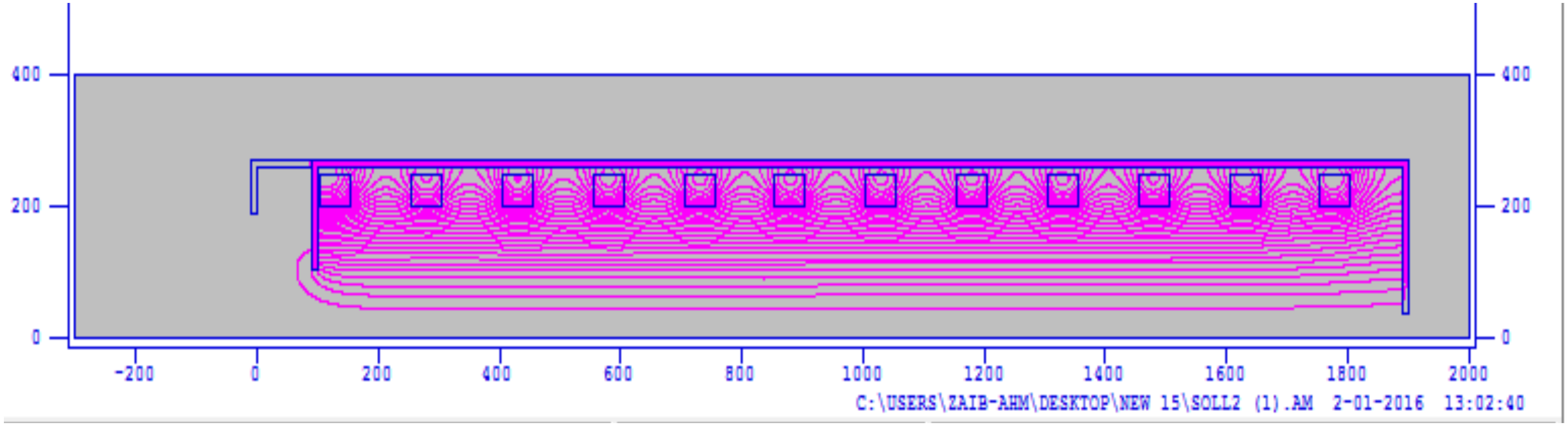
收集极



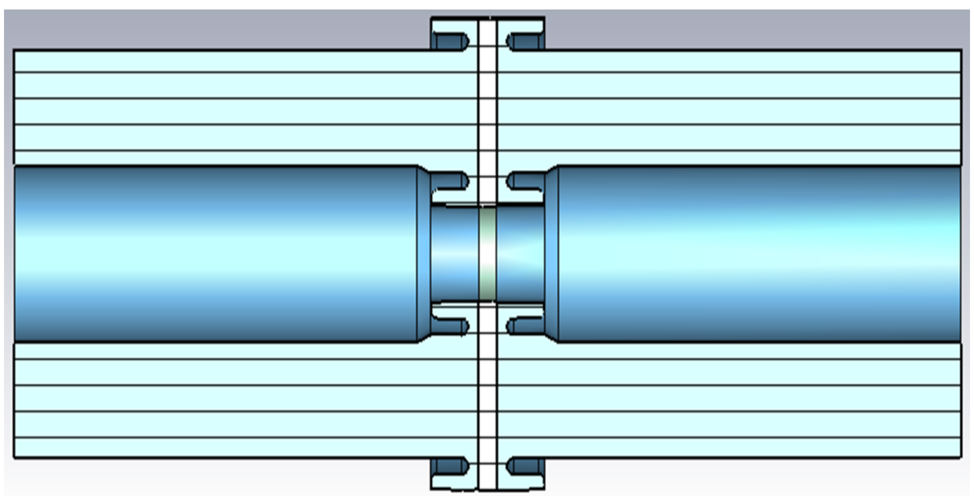


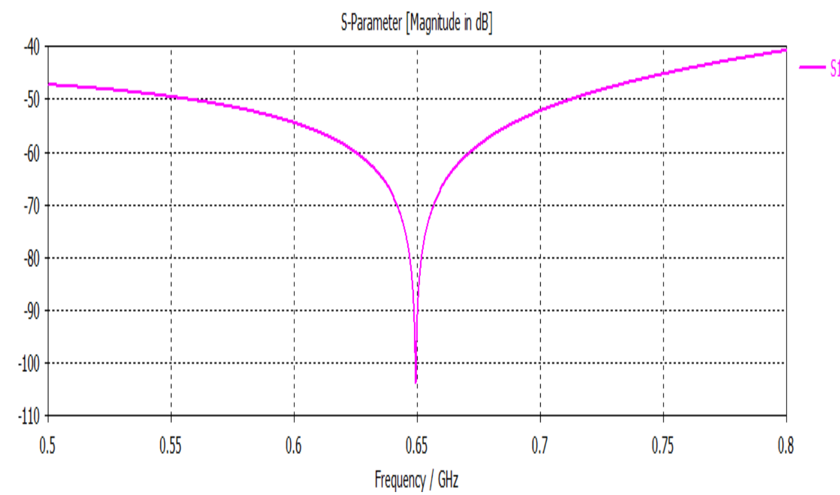
Temperature
Contour 1
4.065e+002
4.002e+002
3.939e+002
3.876e+002
3.813e+002
3.750e+002
3.687e+002
3.624e+002
3.561e+002
3.498e+002
3.435e+002
3.372e+002
3.309e+002
3.246e+002
3.183e+002
3.120e+002
3.057e+002
2.994e+002
2.931e+002
[K]
ANSYS
R15.0
0
0.100
0.200 (m)
0.050
0.150

聚焦系统

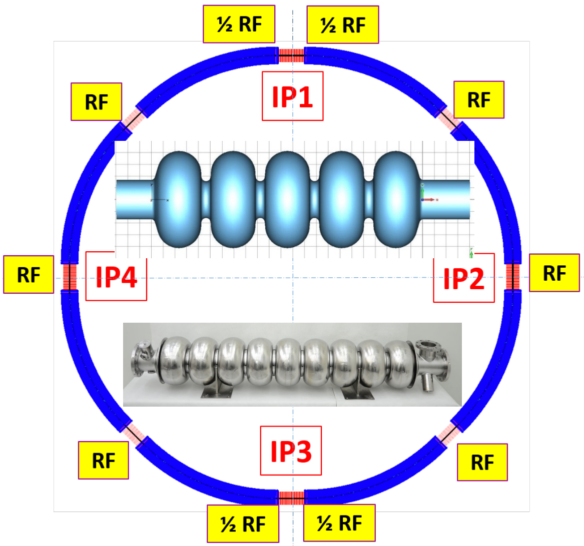

400
200
0
-200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
C:\USERS\ZAIB-AHM\DESKTOP\NEW 15\SOLL2 (1).AM 2-01-2016 13:02:40

陶瓷输出窗

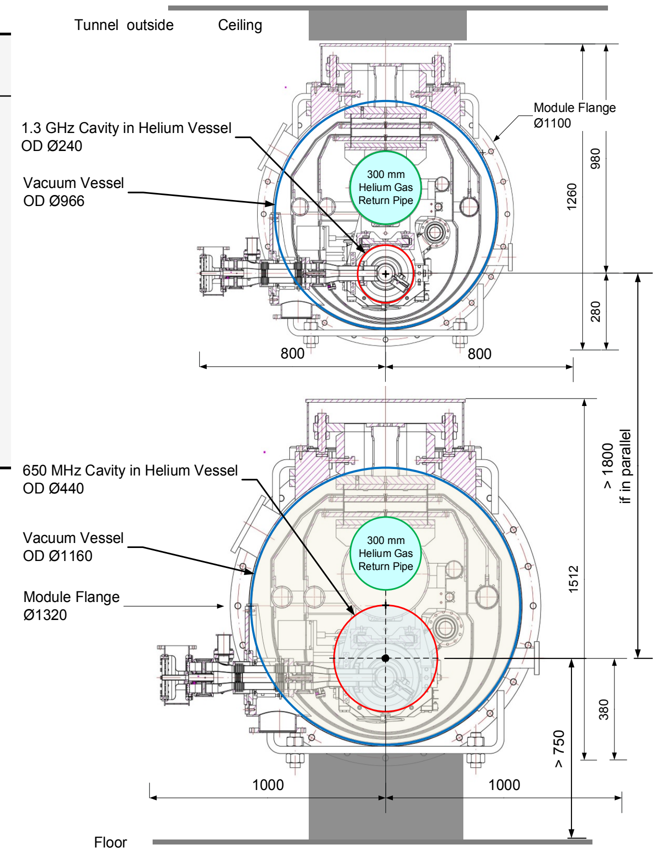



S-Parameter [Magnitude in dB]
-40
-50
-60
-70
-80
-90
-100
-110
0.5
0.55
0.6
0.65
0.7
0.75
0.8
Frequency / GHz
S1,1

超导高频系统



	Collider	Booster
Modules / section	12	4
Module length (m)	10	12
Cavities / module	4	8
Cavities / section	48	32
Total modules	96	32
Total cavities	384	256



- Collider: 650 MHz cavity
- Booster: 1.3 GHz cavity
- Total cavities: 640
- Total modules: 128

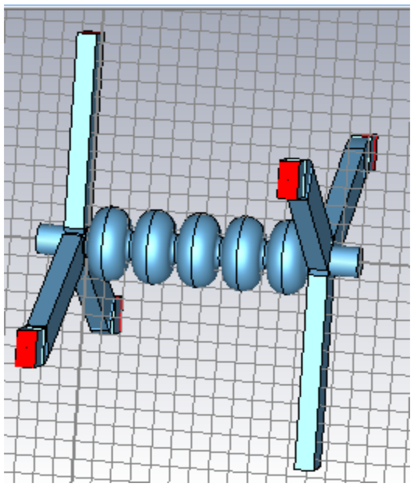
- Total RF length: 1.4 km
- Total RF voltage: 12 GeV
- Beam power: 104.5 MW
- HOM power: 2 MW

Baseline Parameters and Challenges

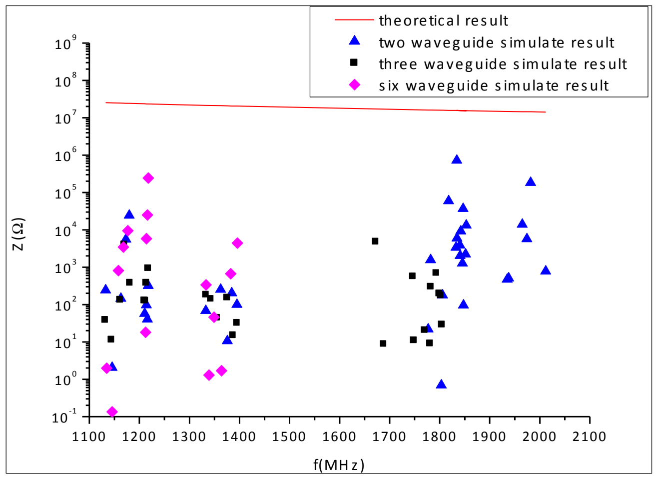
Parameters	CEPC-Collider	CEPC-Booster	LEP2
Cavity Type	650 MHz 5-cell Nitrogen-doped Nb	1.3 GHz 9-cell Nitrogen-doped Nb	352 MHz 4-cell Nb/ Cu sputtered
V_{cav} / V_{RF}	17.9 MV / 6.87 GeV	20 MV / 5.12 GeV	12 MV / 3.46 GeV
E_{acc} (MV/m)	15.5	19.3	6 ~ 7.5
Q_0	4E10 @ 2K	2E10 @ 2K	3.2E+9 @ 4.2K
Cryomodule number	96 (4 cav. / module)	32 (8 cav. / module)	72 (4 cav. / module)
RF coupler power / cav. (kW)	280 c.w.	20	125
RF source number	192 (800 kW / 2 cav.)	256 (25 kW / cav.)	36 (1.2 MW / 8 cav.)
HOM power / cav. (kW)	3.5	0.005	0.3
HOM damper	coaxial/waveguide@2K + ferrite @ RT	coupler @ 2K + ceramic @ 80K	coaxial coupler

■ 高次模及其抑制

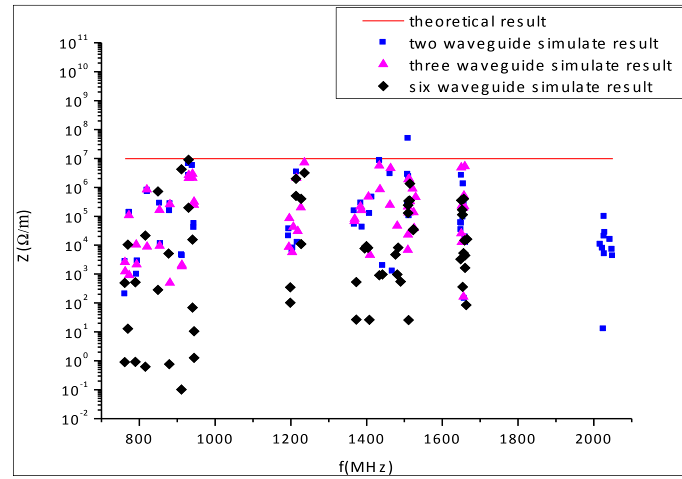
- Need effective damping of the 3.5 kW HOM power per cavity with coaxial coupler or waveguide. Design and simulation ongoing.



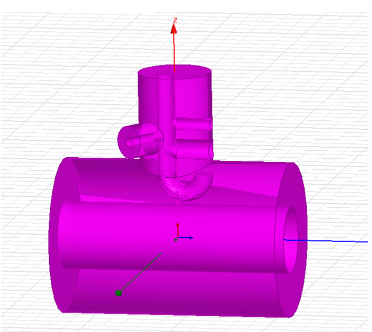
Waveguide HOM coupler



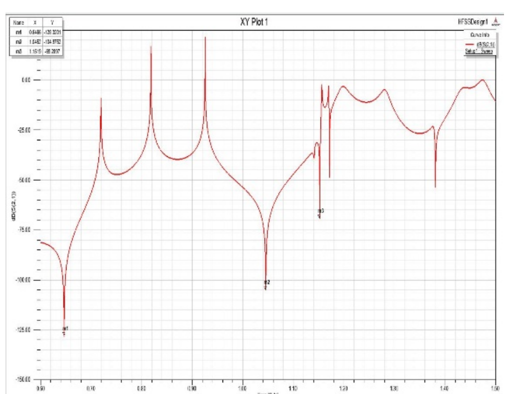
Monopole modes impedance

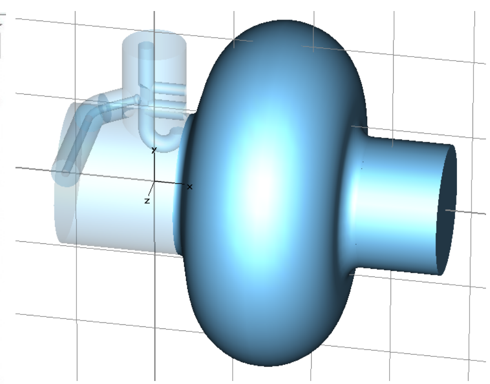


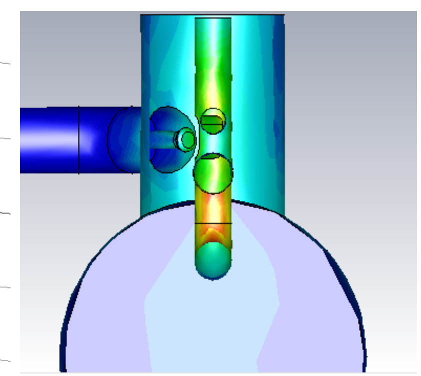
Dipole modes impedance



Coaxial HOM coupler

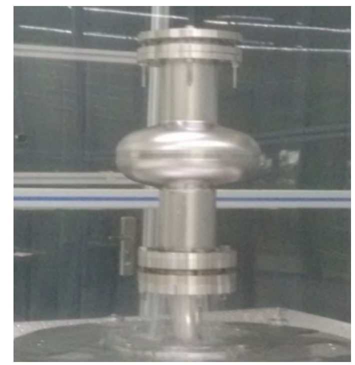






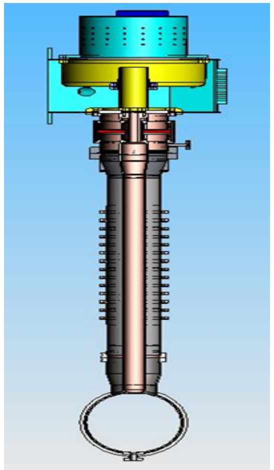
Nitrogen–Doping for high Q_0 cavity

Heating to 800° (7min) → Maintain 10min (7.5E-4 Pa) → N-doping 10min (2.6 Pa) → Maintain 5min (8.5E-4 Pa) → Cool down (311°)

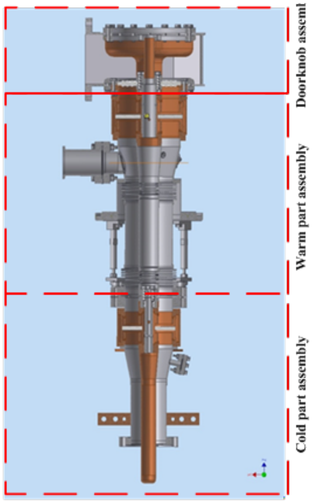


高功率耦合器

- 主环 650MHz 300kW c.w. 耦合器

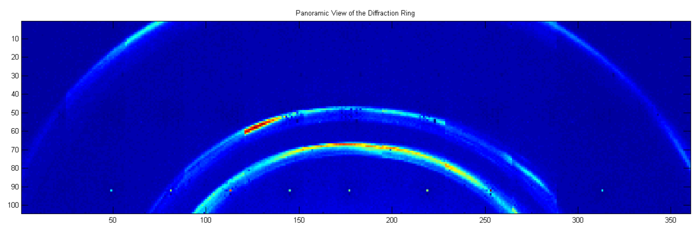


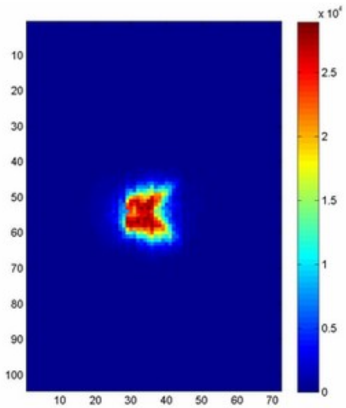
- 增强器1.3 GHz 4kW 耦合器

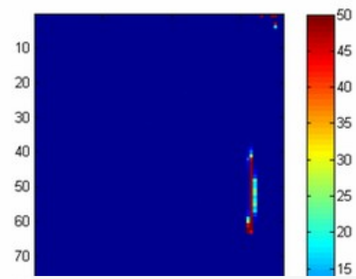


CEPC Detector – Vertex Detector

Wei WEI







- A silicon pixel detector R&D for HEPS is approaching the final step:
  - Pixel size: 150μm×150μm, a single chip with 104×72 array, with a size of 1.7cm×1.1cm
    - The final module of 4.5cm×3.6cm, with 2×4 ASICs
  - A hybrid detector working in single-photon counting mode, 20bit pixel counting-depth, readout by frame refreshing
- Verified performance:
  - Energy range: 6keV~19.5keV, Energy linearity: 2%

/pixel

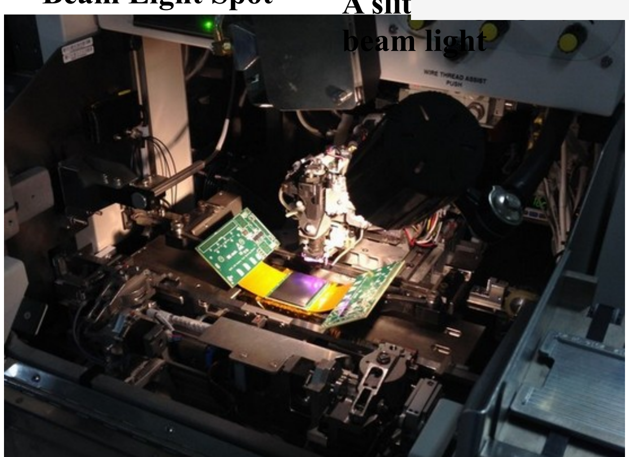
expertize, design team & facility
为CEPC储备

A panoramic view of a diffrac

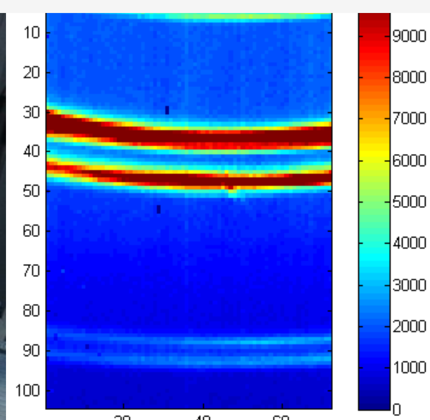
Beam Light Spot

A slit

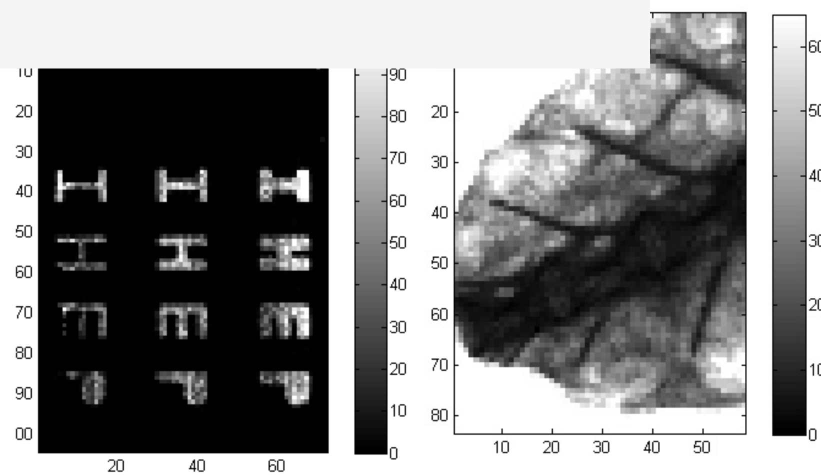
beam light



A full-size tech-trial module under wire-bonding



Diffraction Ring of a Sample



X-ray Imaging at X-ray tube: a laser carved module; the tail of a fish

主 要 内 容

一 引言

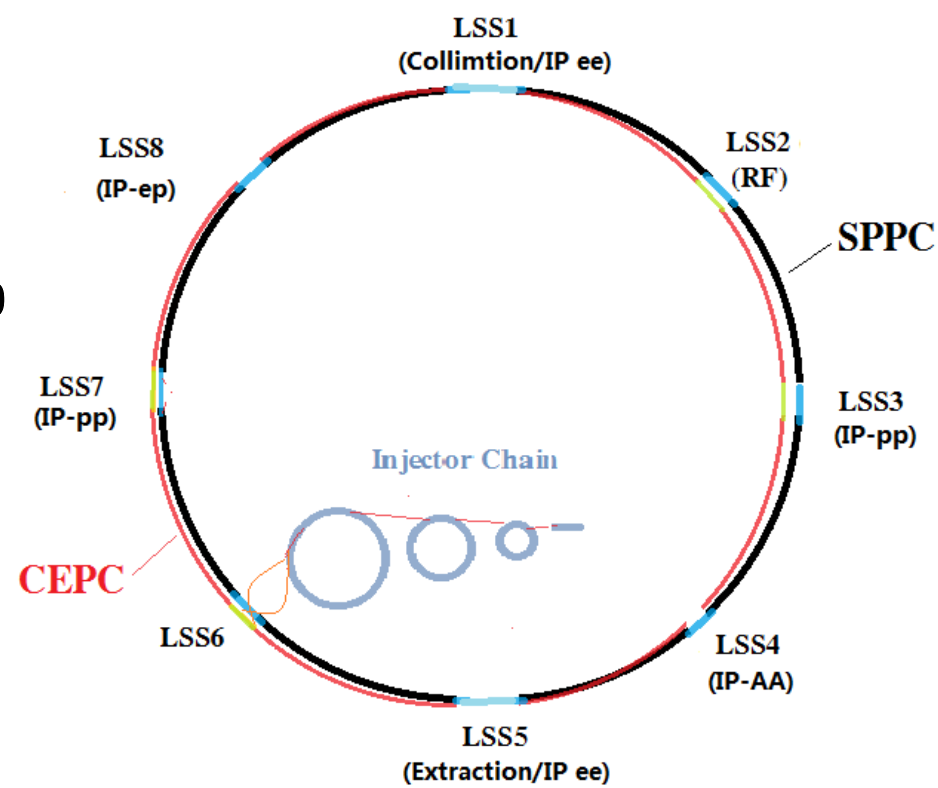
二 CEPC加速器物理与技术研究进展

三 **SppC加速器概要**

四 总结

从CEPC到SppC

- SPPC is the second phase of the project, differing by 10-15 years
- Use the same CEPC tunnel to build SPPC, exploring new physics beyond SM
- Maximize the beam energy to 70-100 TeV range by using 20-T SC magnets (or 16 T for a larger ring)
- Keep the e-rings when adding the SPPC (not the detectors)
- Collisions possible: pp, ep, eA, AA
- Build a new injector chain for SPPC (proton and ions)
- Independent physics programs for the accelerators of the injector chain



从CEPC到SppC

- SPPC main parameters

Parameter	Value	Unit
Circumference	54.36	km
C.M. energy	70.6	TeV
Dipole field	20	T
Injection energy	2.1	TeV
Number of IPs	2	
Peak luminosity per IP	1.2E+35	$cm^{-2}s^{-1}$
Beta function at collision	0.75	m
Circulating beam current	1.0	A
Bunch separation	25	ns
Bunch population	2.0E+11	
SR heat load @arc dipole (per aperture)	56.9	W/m

Main features on accelerator physics

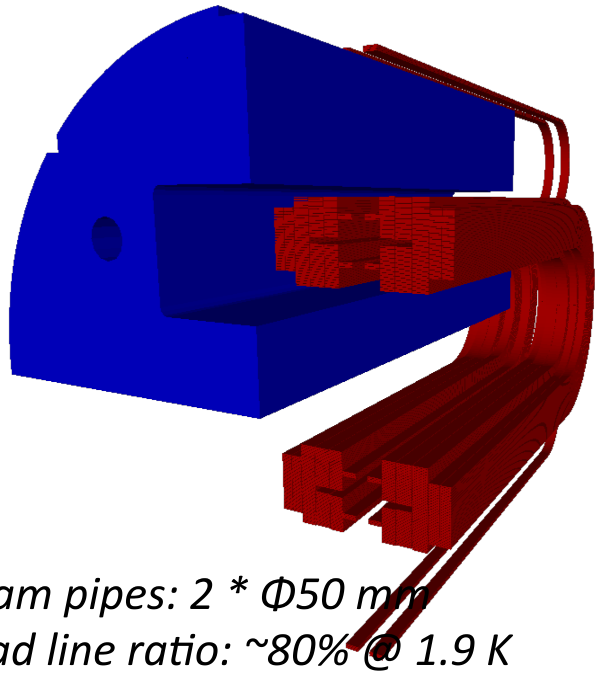
- Very high luminosity: 1.2×10^{35} $cm^{-2}s^{-1}$
  - High efficiency in experiments
  - High integrated luminosity by leveling (synchrotron radiation)
- Very high synchrotron radiation power: 56 W/m @dipole
  - Resulting challenges in both accelerator physics and technology
- Very sophisticated beam collimation system /abort system (6.6 GJ per beam; inefficiency: 10^{-6})
- Challenges in collider lattice design
  - Insertion lattice (IP, collimation, extraction, injection)
  - Compatible with the CEPC rings
- Very complicated injector chain accelerators
  - Four stages, high-power beams, multiple operation modes

Key technical challenges and R&D requirements

— High field SC magnets

- SC dipoles of 20 T are key both in technical challenges and machine cost
  - 2/3 ring circumference
  - Nb_3Sn (15T) +HTS (5T) or pure HTS
  - Twin-aperture: save space and cost
  - Common coils or Cosine-theta type
  - Open mid-plane structure to solve SR problem?
  - SC quads: less number but also difficult

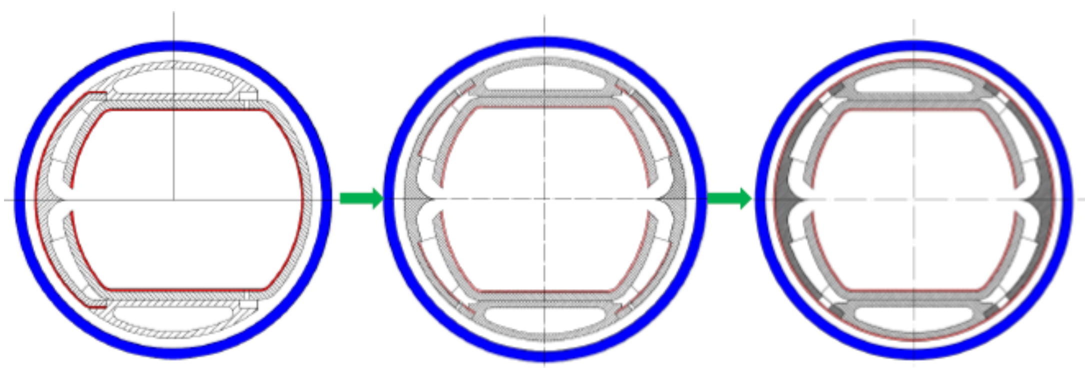
• Domestic and intern. collaboration very important

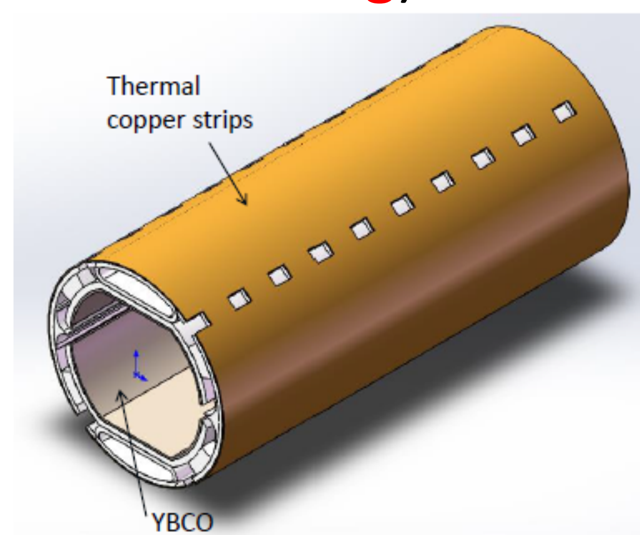


*Beam pipes: 2 * Φ50 mm*
Load line ratio: ~80% @ 1.9 K
Yoke diameter: 800 mm

Beam screen and vacuum

- Beam screen: key issue to solve the problem with very high synchrotron radiation power inside cryogenic vacuum.
  - Need to develop an effective structure and working temperature to guide out the high heat load when minimizing SEY, heat leakage to cold mass, impedance in the fast ramping field, vacuum instability etc.
  - Both design and R&D efforts needed to solve this critical problem.
- New ideas emerge out, SPPC is also investigating feasible structures and coating methods (e.g. YBCO coating)





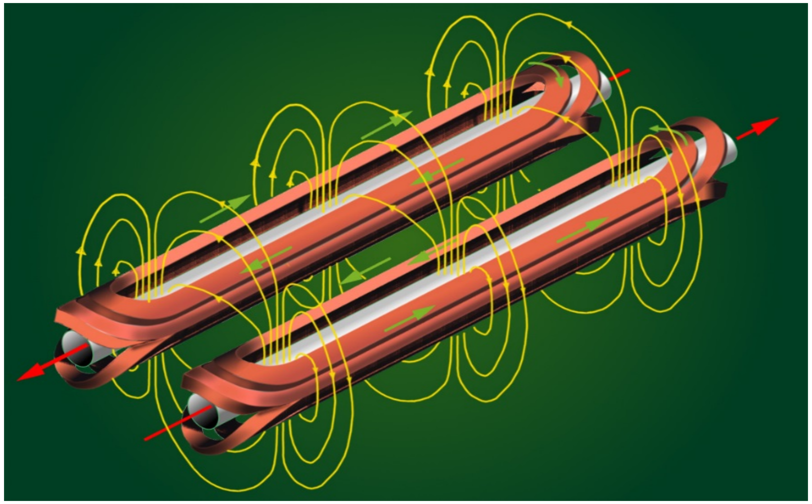
L: FCC ideas
R: study at SPPC

R&D plan of the 20-T magnet technology

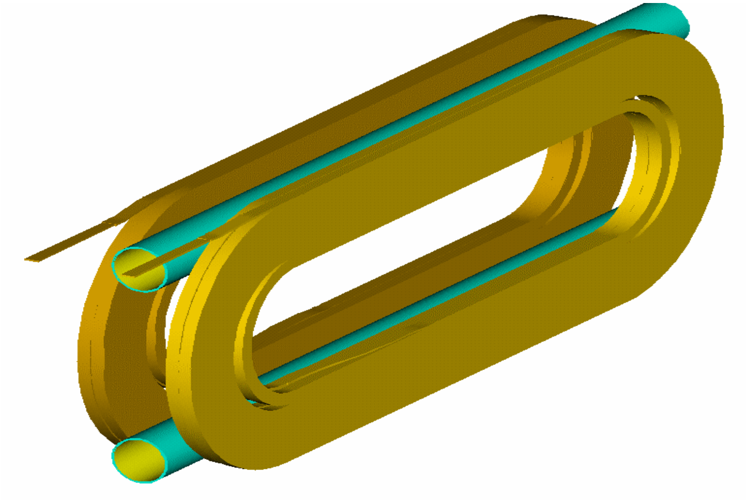
(2015-2020)

High field magnet design study: coil configuration, field quality, stress management;…

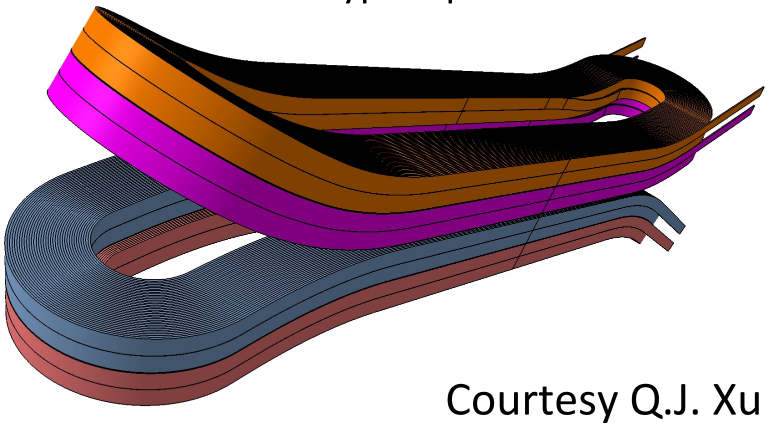
Cos-**th**eta dipole



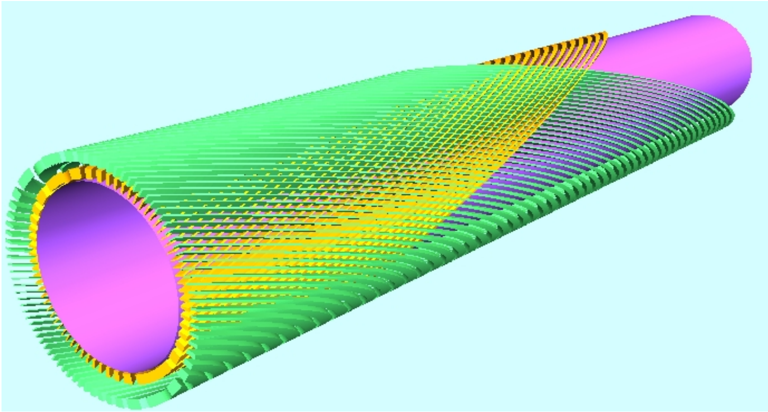
Common coil dipole



Block type dipole



Canted cos-theta dipole



Courtesy Q.J. Xu

20-T magnet working group in China

NIN (Northwest Institute for Non-ferrous Metal Research) & WST (Western Superconducting Tech. Co.)

NIN: Advanced Bi-2212 R&D. Significant progress in past several years.

WST: Qualified Nb_3Sn supplier for ITER. High J_c Nb_3Sn R&D.

Shanghai JiaoTong U.& SST (Shanghai Superconductor Tech. Co.)

YBCO R&D and production. Significant progress in past several years.

Tsinghua U. & Innost (Innova Superconductor Tech. Co.)

10+ years R&D and production of Bi-2223. Modification of production lines for Bi-2212 is under discussion.

CHMFL (High Magnetic Field Laboratory of the Chinese Academy of Sciences)

Nb_3Sn CICC conductor & high field solenoids; advanced insulation materials;…

IHEP (Institute of High Energy Physics, Chinese Academy of Sciences)

Accelerator Center Magnet Group：30+ years R&D and production of conventional accelerator magnets.

Superconducting Magnet Engineering Center：10+ years R&D and production of superconducting solenoids for particle detectors and industries.

And……

More collaborations are needed!

4. 总结

- 继BEPC之后，CEPC-SppC将是中国未来高能物理发展的首要选项
- 2013年以来，CEPC和SppC加速器、探测器设计，物理研究，都取得了很好的进展
- 未来几年时间，对于CEPC加速器关键技术研究，非常重要
- SppC的关键技术，高场超导磁铁，将对未来高能对撞机的建设起到举足轻重的作用

谢 谢！